Th32t Engng.

Technical Paper 292

DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, SECRETARY
BUREAU OF MINES
H. FOSTER BAIN, DIRECTOR

S LIBRARY
SEP 18 1922

TESTS OF GAS MASKS AND RESPIRATORS FOR PROTECTION FROM LOCOMOTIVE SMOKE IN RAILROAD TUNNELS WITH ANALYSES OF TUNNEL ATMOSPHERES

BY

A. C. FIELDNER, S. H. KATZ
and S. P. KINNEY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

Generated on 2024-09-29 23:24 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted, copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Superintendent of Documents *is not an official of the Bureau of Mines.* His is an entirely separate office and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington, D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. The price of this publication is 10 cents.

Persons desiring for lecture purposes the use, free of charge, of lantern slides of the illustrations in this publication, should make request of the Director of the Bureau of Mines, Washington, D. C.

First edition, April, 1922.

Generated on 2024-09-29 23:21 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

CONTENTS.

	Page.
Preface	v
Introduction	1
Composition of normal air	3
Chemistry of combustion	3
Composition of flue gases	4
Physiological effects of flue-gas constituents	5
Carbon dioxide	5
Carbon monoxide	6
Symptoms of carbon monoxide poisoning	7
First-aid treatment for asphyxiation	7
Detection of carbon monoxide	9
Sulphur dioxide	10
Soot, tar, and smoke vapors	10
Suffocation in railroad tunnels	10
Specific instances	11
Giovi Tunnel	11
Ponte Decimo Tunnel	12
Pracchia Tunnel	12
Grand Trunk Tunnel under St. Clair River	12
Tunnel No. 3, Summit, Wis	12
Schenley Tunnel, Pittsburgh, Pa	12
Experiments on the use of gas masks in railroad tunnels	13
Description of gas masks used in tests	13
Army gas mask	13
Carbon monoxide mask	14
Pocket canisters	14
Tests in West Virginia tunnels	15
Discussion of results of West Virginia tests	16
Tests in the Gallitzin Tunnels	19
Tests in the Schenley Tunnel	20
General discussion of results of tests	23
Type of gas mask or respirator best suited for use in tunnels	24
Other uses of the pocket canister	25
Summary and conclusions	26
Acknowledgments	26
Publications on gas masks and breathing apparatus	27

TABLES.

	Page.
TABLE 1. Composition of normal air, locomotive stack gases, and tunnel atmospheres	5
2. Location, lengths, and grades of Baltimore & Ohio R. R. tunnels, Parkersburg branch, Monongah division	16

Generated on 2024-09-29 23:21 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Page.

TABLE 3. Results of tests in locomotive cabs in tunnels of Baltimore & Ohio R. R. between Grafton and Parkersburg, W. Va..... 17
4. Results of tests in locomotive cabs in Gallitzin No. 4 track tunnel, Pennsylvania R. R..... 19
5. Analyses of air breathed by trackworkers after passage of trains in Schenley Tunnel, Baltimore & Ohio R. R., Pittsburgh, Pa..... 22

ILLUSTRATIONS.

Page.

PLATE I. *A*, Rectangular pocket canister in use; *B*, Pocket canister with curved mouthpiece; *C*, Army gas mask worn in tests through tunnels on Monongah division, B. & O. R. R..... 14
II. *A*, Drum canister with chin rest to reduce strain on teeth; *B*, Drum canister..... 15
III. *A*, Schenley Tunnel, B. & O. R. R., at Pittsburgh, before passage of train; *B*, Smoke from Schenley Tunnel after passage of train..... 20
FIGURE 1. Schaefer, or prone method of artificial respiration (inspiration)..... 8
2. Schaefer, or prone method of artificial respiration (expiration)..... 8
3. Details of rectangular pocket canister..... 15

Generated on 2024-09-29 23:21 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

PREFACE.

The tests described in the following report represent one phase of the work carried on by the gas-mask laboratory of the Bureau of Mines at Pittsburgh, Pa. For many years the bureau has been making experiments and tests to improve and perfect self-contained oxygen breathing apparatus for the conduct of rescue work at mine disasters resulting from fires or explosions. As a result of its experience, it was called on, early in the war, to take a large part in the development of the Army gas mask.

More recently, it has investigated the Army type of mask for the purpose of determining whether or not that type could be so modified as to be of service in work about smelters, blast furnaces, or similar industrial operations, or possibly even about mines. This investigation has shown that the Army type of mask, while affording protection against all the gases met in warfare, does not afford protection against all gases met in industrial life. More especially, it does not protect against carbon monoxide, the gas hazard in coal mines, at gas producers, etc., nor against such common industrial gases as illuminating gas, natural gas, ammonia, and the products of combustion found in burning buildings.

For this reason, the bureau has sought to impress on the public the limitations of the Army gas mask and at the same time to develop special types of masks suitable for different industries or occupations, that will serve to protect the wearer from the gas hazards encountered in a particular field of work. The bureau has also done work on a "Universal" mask that would serve to protect the wearer against all of the gases in air commonly met.

A light weight form of this universal mask has been developed for the use of city firemen and has been appreciated by fire departments.

The type of respirator described in the following report is for the use of locomotive crews and is designed only to afford protection against the conditions commonly met by them.

It is essential, however, that respirators of this type should be used only under the conditions existing in the occupation for which it is

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

designed or for which careful experiment has demonstrated its effectiveness. None of the three types mentioned—the Army mask, the firemen's mask, or the locomotive tender's mask—should ever be used in mines, for any attempt to utilize them there would only increase the hazard of the wearer. Prospective users of gas masks should invariably ascertain the limitations of the type of mask under consideration and assure themselves that the mask selected will afford the needed protection under all the conditions that are likely to be encountered.

H. FOSTER BAIN,
Director.

Generated on 2024-09-29 23:19 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

TESTS OF GAS MASKS AND RESPIRATORS FOR PROTECTION FROM LOCOMOTIVE SMOKE IN RAILROAD TUNNELS, WITH ANALYSES OF TUNNEL ATMOSPHERES.

By A. C. Fieldner, S. H. Katz, and S. P. Kinney.

INTRODUCTION.

The extreme discomfort caused by breathing sulphurous locomotive smoke while a train is passing through a tunnel is familiar to anyone who has ever been a passenger in a coach near the locomotive, especially if all the windows are not carefully closed. Bad as these conditions are for the coach passengers, they are almost intolerable in the engine cab where the hot smoke and exhaust steam direct from the stack envelopes the cab and fills it with hot, choking gases. An investigator[1] for the West Virginia Public Service Commission who rode the second engine of a double header through a long unventilated tunnel reports his experience as follows:

> The writer in passing through this tunnel experienced conditions that were as nearly unbearable as it was possible for him to realize. Although before entering the tunnel he had saturated a handkerchief with water and placed same over his mouth and nose, by the time he was halfway through the tunnel he was gasping for breath and felt as if there was a question whether he would survive the ordeal. Breathing was exceptionally difficult and he feels he would not care to undertake a trip on a double header more often than could possibly be avoided. Men should not be asked to work under such conditions, as it is about the limit of human endurance.

Aside from the question of extreme discomfort, locomotive smoke may contain poisonous and asphyxiating constituents which have occasionally overcome, sometimes fatally, numbers of the crew of engines that have become stalled in poorly ventilated tunnels. A number of such cases are on record.

In a tunnel the tunnel crown deflects the smoke from the stack upon and around the locomotive. Mixed with air and exhaust steam, the smoke enters the cab and surrounds the engineer and fireman with

[1] Bachelder, F. J., Report to the Public Service Commission, State of West Virginia, upon tunnel ventilation, Baltimore & Ohio Railroad tunnels between Grafton, W. Va., and Parkersburg, W. Va.: Public Service Commission, Charleston, W. Va., March 10, 1916, p. 26.

Generated on 2024-09-29 23:19 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

a hot, vitiated atmosphere. Discomfort produced by the sulphurous smoke is intensified by the heat and humidity from the flue gases and exhaust steam. Slow, heavy freights going up grade through long, unventilated tunnels cause the most discomfort, especially when two or more locomotives are used; and when trains become stalled the crews are in danger of being overcome, as has been reported on unusual occasions.[2] Carbon monoxide from locomotive flue gas, augmented in its effect by the high temperatures, is the probable cause of such cases of men being overcome.

Respirators of the "pig-snout" type containing wet sponges afford some relief by cooling the gases and absorbing some of the irritating constituents of smoke. Protection is not complete and most of the men will not bother with such respirators, preferring to tie handkerchiefs over the nose and mouth.

As there is evidently a need for a simple but effective respirator or gas mask that can be put on quickly and worn with comfort, members of the Bureau of Mines tested the Army gas mask and various forms of special masks on locomotives in railroad tunnels to determine whether any simple form of gas mask or respirator could be used to alleviate the discomfort to which the engine crew is subjected. It was found that Army gas masks, having canisters filled with charcoal and soda-lime mixture and with a cotton-pad filter, gave good protection against the smoke and irritant gases. However, one constituent of smoke, carbon monoxide, which is poisonous but tasteless and odorless, penetrates these canisters. Fortunately experience has proven and analyses taken during the tests showed that on moving trains the amount of carbon monoxide present was not enough to be dangerous. The air delivered by the canisters was cool in spite of the fact that temperatures at the cab were determined up to 162° F., because the material in the canister has a considerable capacity for absorbing heat.

On account of its bulk and inconvenience the Army gas mask did not meet the full approval of the trainmen, therefore smaller canisters were designed of a size to fit easily into a coat pocket and with a mouthpiece attached directly to the canisters; the mouthpieces were made with both straight and curved stems after the fashion of tobacco pipes. These small "smoke respirators" (Pl. I, *A* and *B*) have had the hearty approval of the men who have used them, and in actual service have retained their effectiveness for months. They may be

[2] Editorial: Railway and Eng. Review, vol. 44, 1904, p. 140.
Fox, Francis, The ventilation of tunnels and buildings: Proc. Inst. Civ. Eng., vol 136, 1898, pp. 1–20, discussion, pp. 21–87.
Fox, Francis, The ventilation of tunnels: Eng. News, vol. 42, 1899, pp. 131–135.
Bachelder, F. J., Report to the Public Service Commission upon tunnel ventilation, Baltimore & Ohio Railroad tunnels between Grafton, W. Va., and Parkersburg, W. Va.: Public Service Commission, Charleston, W. Va., March 10, 1916, 44 pp.

Generated on 2024-09-29 23:21 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

cheaply made and are a great improvement over the sponge respirators and handkerchiefs and towels now used by engineers and firemen when passing through unventilated tunnels.

COMPOSITION OF NORMAL AIR.

Normal or ordinary pure dry air is a mechanical mixture of the gases oxygen, nitrogen, and carbon dioxide, and consists approximately of four volumes of nitrogen to one volume of oxygen; in more exact figures the composition is usually given as follows:

Composition of pure dry air.	Per cent by volume.
Carbon dioxide (CO_2)	0.03
Oxygen (O_2)	20.93
Nitrogen (N_2)	79.04
	100.00

This composition remains the same for pure dry air all over the globe. However, ordinary air is never perfectly dry, but always contains some water vapor, the proportion varying with the temperature and the humidity. The higher the temperature the more water air can hold without the moisture becoming visible as steam or fog. Air is said to be saturated at a given temperature when it contains the maximum content of invisible water vapor. If this saturated air is cooled some of the water condenses out in the form of visible particles, forming steam or fog. As the water content of air is constantly changing with atmospheric conditions, the chemist usually expresses his gas analyses in terms of the proportions of dry gases or dry air. None of the gases in air are chemically combined with each other, and artificial air can easily be made by simply mixing the proper proportions of carbon dioxide, oxygen, and nitrogen.

CHEMISTRY OF COMBUSTION.

Men and animals require oxygen; they constantly remove it from the air they breathe and return carbon dioxide in the air they exhale. Likewise in the burning of coal, wood, and other fuels, oxygen from the air combines with the carbon and hydrogen of these substances, forming carbon dioxide and water vapor which goes back into the air. This union of oxygen with carbon and hydrogen, whether it occurs in the body of man and animals or in the burning of fuels, gives off heat, and both processes are termed oxidation. The more rapid oxidation of fuels with production of noticeable light and heat is usually called combustion, while slower processes, as for example the rusting of iron, are usually called oxidation. The term oxidation includes combustion, as does any process in which oxygen combines with other substances.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

The nitrogen in air serves as a diluting medium and thus slows up the speed of combustion. If air were pure oxygen, things would burn much faster when ignited. Likewise when the oxygen content of air is reduced below the normal 20.93 per cent, combustion is retarded. At least 17 per cent oxygen in air is required to keep a candle flame or miner's oil lamp ignited. If the percentage of oxygen falls to 16 per cent, the flame at once goes out. An acetylene lamp will burn in air that contains only 12 to 13 per cent oxygen. This percentage is also about the minimum that a man can safely endure.

As previously stated, air is a mixture of oxygen, nitrogen, carbon dioxide, and water vapor; the oxygen and nitrogen are elements, and the carbon dioxide and water vapor are compounds. Carbon dioxide is composed of one atom of carbon combined with two atoms of oxygen. This combination results from the complete burning of carbonaceous substances such as coal, wood, and oil in the presence of plenty of air. When the air supply is shut off from a fire so as to choke down the flame, combustion becomes incomplete and part of the carbon combines with only one atom of oxygen and forms an entirely different gas, a very poisonous one called carbon monoxide, of which more will be said later.

Water is also a compound formed by the combination of two atoms of hydrogen with one atom of oxygen. Water vapor, then, is the product of combustion of the element hydrogen, which is present in most fuels. Similarly, the sulphur in coal burns to sulphur dioxide, a pungent, irritating gas, composed of one atom of sulphur and two atoms of oxygen.

When a man breathes, the blood in the lungs absorbs the oxygen from the air and carries it to all parts of the body. Here it oxidizes carbon to carbon dioxide and hydrogen to water, with the production of heat and energy. Carbon dioxide is given off in the exhaled air, the amount varying with different individuals and the work being performed. Four per cent is an average figure for the carbon dioxide in exhaled air.

COMPOSITION OF FLUE GASES.

The contamination of the atmosphere of a railroad tunnel is produced solely by the flue gases and smoke particles from the steam locomotive. The actual composition of these gases varies with the coal used, the method of firing, and the excess of air admitted to the fire box. The range of composition of locomotive stack gases in comparison with that of normal air and atmospheres as found in tunnels while the train was passing through, is given in Table 1.

Generated on 2024-09-29 23:22 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

TABLE 1.—*Composition of normal air, locomotive stack gases, and tunnel atmospheres.*

Gas.	Percent by volume.		
	Air.	Locomotive stack gases.	Tunnel atmosphere.
Oxygen	20.93	3 -10	19.67-20.93
Nitrogen	79.04	79 -82	78.99-79.12
Carbon dioxide	.03	8 -14	0.03- 1.03
Carbon monoxide	None.	0.1 - 4	0.0 - 0.12
Sulphur dioxide	None.	0.05- 0.3	0.0 - 0.02

The flue gas from a furnace burning coal is made up of the unconsumed portions of the air supplied to the fire—that is, all of the nitrogen and some of the oxygen, the products of combustion of the fuel which consist of carbon dioxide, water vapor, and smaller quantities of carbon monoxide and sulphur dioxide, and small amounts of unconsumed distillation products such as hydrogen and methane from the freshly heated coal, with smoke particles of soot, mostly free carbon.

If the combustion in the fire box were complete, flue gas would not contain any carbon monoxide, hydrogen, methane, or soot. However, conditions in locomotive firing are such that small quantities of these substances are almost always present and immediately after firing there may be a considerable quantity. For this reason locomotives are seldom fired just before entering or while passing through a tunnel.

PHYSIOLOGICAL EFFECTS OF FLUE-GAS CONSTITUENTS.

Carbon dioxide, sulphur dioxide, and carbon monoxide are the only constituents of flue gas that are dangerous to life. The other gases, hydrogen and methane, have no effect other than cutting down the proportion of oxygen in the air. Furthermore their proportion is so small that they need receive no further consideration.

CARBON DIOXIDE.

A man can breathe air containing up to approximately 3 per cent carbon dioxide without particularly noticeable effect, except a slight increase in the rate of breathing. An increase of the percentage to 5 or 6 per cent causes panting and throbbing of the heart, and makes the face flushed. Higher percentages are asphyxiating and cause death, especially if the breather is exerting himself. It is rather unlikely that carbon dioxide would accumulate to these percentages in railroad tunnel atmospheres, hence it is probably the least troublesome of the three gases mentioned.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

CARBON MONOXIDE.

Carbon monoxide is formed by the incomplete combustion of carbonaceous materials. It is the poisonous constituent that is probably responsible for such deaths as have occurred from breathing air heavily contaminated with smoke from stalled locomotives in poorly ventilated tunnels.

Carbon monoxide is insidious in its action on man because it has no odor, taste, or color, and does not irritate the eyes or throat, the irritation from smoke being due to other constituents that are not very poisonous. Carbon monoxide is poisonous because it combines with the red coloring matter of the blood more readily than oxygen does, and blood that is saturated with carbon monoxide can not take up oxygen as it should. A few breaths of air containing 2 per cent carbon monoxide will produce unconsciousness and death almost as quickly as drowning.

The effect of carbon monoxide on man depends upon the amount in the air, the length of time it is inhaled, and the exertion the man is making. A very low percentage breathed over a long period of time has the same effect as a high percentage over a short period of time. Death is likely to ensue when a man breathes air containing 0.2 per cent carbon monoxide for 4 or 5 hours, or 0.4 per cent for 1 hour. These are rough figures only, as a man working vigorously breathes six to eight times as fast as a man at rest and will, therefore, be overcome sooner. Moreover, men differ in their susceptibility to carbon monoxide poisoning.

Burrell[3] says that he was very sick for 8 hours after exposing himself for a period of 20 minutes to an atmosphere containing 0.25 per cent of this gas. During this time he did not exert himself. It is evident that relatively short exposure, of say 20 to 30 minutes, to any percentage above 0.25 per cent must be regarded as distinctly dangerous to man, even when not working. Men exerting themselves vigorously may breathe eight times as fast as when at rest, and thus be overcome by carbon monoxide much sooner. Under such conditions percentages as small as 0.10 to 0.15 per cent may become dangerous, especially if such an atmosphere is inhaled for more than 15 minutes. Recent experiments by Henderson in connection with the ventilation of the Hudson River vehicular tunnel show that a man at rest can breathe 0.04 per cent carbon monoxide for 1 hour without any noticeable ill effect; 0.06 per cent caused a slight headache in a few individuals.[4]

---

[3] Burrell, George A., and Seibert, Frank M., Gases found in coal mines: Miners' Circ. 14, Bureau of Mines, 1916, p. 20.

[4] Henderson, Y., Haggard, H. W., Teague, M. C., Prince, A. L., and Wunderlich, R. M., Physiological effects of automobile exhaust gas and standards of ventilation for brief exposures: Jour. Ind. Hyg., vol. 3, July, 1921, pp. 79–92; Aug., 1921, pp. 137–146.

Generated on 2024-09-29 23:24 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

SYMPTOMS OF CARBON MONOXIDE POISONING.

According to Foster and Haldane [5] and to Henderson [6] the symptoms of carbon monoxide poisoning are much the same as those produced by air from which the oxygen has been burned out, and vary according to the degree of saturation of the blood with the gas. With a 20 per cent saturation, the only symptom is a slight tendency to dizziness and shortness of breath on exertion. As the saturation increases, however, the symptoms of want of oxygen become more and more pronounced, until at 50 per cent saturation the breather can hardly stand, and even slight exertion causes loss of consciousness. The onset of the symptoms is very insidious, there being only slight shortness of breath and palpitations, but hardly any discomfort and the senses, power of judgment, and movement are commonly much impaired before the person is aware of anything being wrong. In some cases, there is much excitement, but often there is simply drowsiness and stupidity. The symptoms are in some respects similar to those produced by alcohol. One curious fact is that in carbon monoxide poisoning, as in alcoholic poisoning, sudden exposure to cool fresh air may greatly increase the symptoms. Death seems often to be brought about immediately by muscular exertion, as in attempts to escape rapidly up ladders, inclines, etc. If death occurs gradually, the haemoglobin (red coloring matter of the blood) is usually found to be 80 per cent saturated with carbon monoxide. Persons who have been rescued alive, but still unconscious, after long exposure to carbon monoxide, often die later in consequence of the damage to the tissues during exposure.

The reverse process of freeing the blood from carbon monoxide begins when fresh air is supplied, and if the breathing is vigorous it may proceed quite rapidly. The ill effects, however, do not pass off so rapidly, but may persist for hours, days, weeks, or throughout life. Most of the harm has been done before the man reaches fresh air, and the ill effects may come later. For this reason it is better to send fresh men into a place where carbon monoxide is expected rather than men who have previously breathed the gas.

FIRST-AID TREATMENT FOR ASPHYXIATION.[7]

Apply artificial respiration as soon as the victim has been removed to the fresh air. The Schaefer, or prone, method of artificial respiration is performed as follows:

Place the person on his abdomen; remove from his mouth all foreign bodies, such as false teeth, tobacco, and gum; the tongue usually falls forward of its

[5] Foster, C., and Haldane, J. S., The investigation of mine air, London, 1903, pp. 146–7.

[6] Henderson, Y., Carbon monoxide poisoning: Jour. Amer. Med. Assoc., vol. 67, 1916, pp. 580–583.

[7] Halberstadt, G. H., Knoefel, A. F., Lynot, W. A., Rountree, W. S., and Shields, M. J., Manual of first-aid instructions for miners, revised by R. R. Sayers: Bureau of Mines, 1921, pp 33–37.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

own weight, but see that it is kept forward; turn his head to one side and rest it on his forearm, so that the mouth and the nose will not come in contact with the ground, and extend the other arm forward. If the person is thin, prepare a pad of folded clothing, blankets, or brattice cloth and place it under the lower part of his chest. Do not make this pad too thick. Do not wait to loosen the victim's clothing, but begin artificial respiration without delay. An assistant may remove all tight clothing from the victim's neck, chest, and waist; blankets, hot-water bottles, safety lamps, or hot bricks well wrapped in paper or cloth should be placed about the person by an attendant.

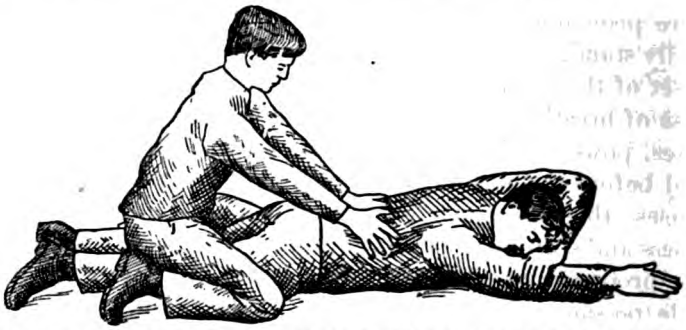


FIGURE 1.—Schaefer, or prone method of artificial respiration (inspiration).

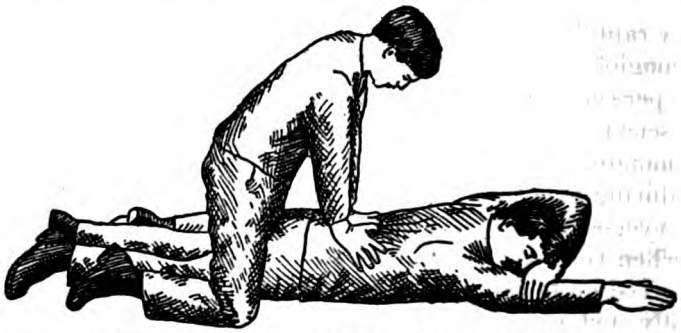


FIGURE 2.—Schaefer, or prone method of artificial respiration (expiration).

Kneel, straddling the person's thighs and facing his head; the palms of your hands are placed over the short ribs with your thumbs parallel with the spine about 2 inches apart and your fingers spread out as much as possible, the ends of the little fingers reaching just below the last rib (see fig. 1), with arms held straight; swing forward slowly so that the weight of your body is gradually brought to bear on the person (see fig. 2). This operation, which should take about two seconds, must not be violent, lest the internal organs be injured. The lower part of the chest and also the abdomen are thus compressed and air is forced out of the lungs. Now, immediately swing back slowly to remove the pressure, but leave your hands in place, thus returning to the position shown in figure 1. Through their elasticity the patient's chest walls expand and his lungs are thus supplied with fresh air. After two seconds swing forward again and repeat deliberately about 15 times a minute; the double movement of compressing and releasing, causing a complete respiration in about four seconds. If a watch or clock is not available, follow the natural

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

rate of your own deep breathing, swinging forward with each expiration and backward with each inspiration.

Continue artificial respiration, if necessary, for at least three hours without interruption, or until natural breathing has been restored or until a physician has arrived. Even after natural breathing begins, carefully watch that it continues. If it stops, start artificial respiration again.

Do not give any liquids whatever by mouth. Do not permit bystanders to crowd around. The assistant should not do anything that will interfere with the operator.

As pointed out in Technical Paper 77[8] of the Bureau of Mines, in mild cases of respiratory failure, or even when breathing is suspended, manual methods should be used at once, because there is a chance of reviving the patient if they are, but "if, owing to delay, the cells of the brain have been deprived of their supply of oxygen for more than the critical period (rarely more than 10 minutes), it is utterly impossible for any later treatment to restore them to their normal condition."

However, as the breathing may be so faint that it will not be detected by the layman or first-aid man, even if the person seems to be dead, it is advisable that artificial respiration be begun at once and continue until there is no hope of reviving him.

When the quantity of fresh air supplied to the patient by artificial respiration is small or insufficient, as is likely to be the case if the patient has been breathing poisonous gases, it is advisable that the manual method be supplemented by the release of pure oxygen from a container in proximity to the patient's nose or mouth, but without creating any pressure that would cause injury or prevent free exhalation. When oxygen or oxygen and air are given the manual treatment should not be stopped but should continue as long as there is hope of reviving the patient.

Various machines have been devised to compel or assist artificial breathing. The committee on resuscitation (authors of Technical Paper 77) considered that devices that automatically force respiration are dangerous, and at the time of preparing this report official approval has not been given to any resuscitation devices.

DETECTION OF CARBON MONOXIDE.

Mice and birds, preferably canary birds, are used in mines by the Bureau of Mines rescue parties for detecting carbon monoxide because they are much more sensitive to the poisonous action of the gas than are men. If an exploring party with birds enters a suspected atmosphere cautiously, it will be able to make escape safely if it leaves promptly when the birds show signs of distress.

[8] Cannon, W. B., Crile, G. W., Erlanger, J., Henderson, Y., and Meltzer, S. J., Report of the committee on resuscitation from mine gases: Tech. Paper 77, Bureau of Mines, 1914, 36 pp.

Generated on 2024-09-29 23:24 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

A device developed in the Chemical Warfare Service of the Army called the "Hoolamite" carbon monoxide detector indicates carbon monoxide in concentrations of 0.07 per cent or more by the change of color of a granular material in a small glass tube when the gas is drawn through it.[9] This device is light and simple and may be used by anyone. Although it has not as yet been extensively tested in actual use, it seems to be an important aid in detecting dangerous concentrations of carbon monoxide.

SULPHUR DIOXIDE.

The average person can not breathe more than 0.005 per cent sulphur dioxide in air for any length of time, and 0.05 per cent is so acutely pungent as to cause a sensation of suffocation even with the first breath.

The percentage of sulphur dioxide in tunnel gases is never large enough to be dangerous, but it does cause very much discomfort due to its irritating action on the eyes and throat. This is especially noticeable when high-sulphur coal is used.

SOOT, TAR, AND SMOKE VAPORS.

The irritation produced by locomotive smoke is due not only to sulphur dioxide but to solid particles of ash, cinders, soot, and tar, and to certain smoke vapors. None of the latter substances are poisonous, but they are extremely disagreeable to the men in the cab, who breathe these substances, direct from the stack, at an uncomfortably high temperature and mixed with the hot exhaust steam. Heat radiated from the boiler and hot fire box combined with the cloud of hot smoke and exhaust steam produces temperatures in the cab 50 to 100° F. higher than the normal tunnel temperature. No doubt these excessive temperatures and the moisture-saturated atmosphere contribute to the general ill effect of the asphyxiating gases.

SUFFOCATION IN RAILROAD TUNNELS.

Actual danger from a deficiency of oxygen in railroad tunnel atmospheres is very unlikely, as a man can work in atmospheres containing only 12 per cent oxygen, although an oil flame will not burn in atmospheres containing less than 17 per cent oxygen. The carbon monoxide given off by a locomotive would overcome men long before the oxygen deficiency could reach 12 per cent.

---

[9] Harrington, D., and Dyer, B. W., Test of carbon monoxide detector which shows green when that gas is present: Coal Age, vol. 19, Feb. 10, 1921, pp. 269–270.

Lamb, A. B., Bray, W. C., and Frazer, J. C. W., The removal of carbon monoxide from air: Jour. Ind. and Eng. Chem., vol. 12, Mar., 1920, pp. 213–221.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Short tunnels are sufficiently ventilated by the natural circulation of the air and by the motion of the train. But many of the longer tunnels, especially those in which traffic is heavy, are provided with mechanical ventilation, or electric locomotives have been substituted for steam locomotives. The Saccardo[10] system of ventilation is used in Europe and the Wentworth-Churchill[11] system, a modification of the Saccardo, is largely used in the United States. An air current of 6 to 10 miles per hour is induced through the tunnel by means of a fan in a small auxiliary tunnel at one end of the main tunnel, and usually at the bottom of an ascending grade. The air from the fan is discharged at a high velocity from a series of nozzles located in the periphery near the ends of the tunnel and almost parallel to the axis of the tunnel.

A heavy train going up grade through the tunnel travels slightly slower than the air current, so that all the smoke is carried through and out of the tunnel in advance of the train.

SPECIFIC INSTANCES.

A review of the literature on tunnel ventilation discloses a number of instances of members of the train crews or other workmen being overcome in tunnels from the effects of excessive temperatures and locomotive flue gases—usually when heavy trains with more than one locomotive became stalled in long unventilated tunnels, and the large quantities of smoke contaminated the air with enough flue gas to cause suffocation or exhaustion, the high temperatures and humidities no doubt contributing to this result. In several instances death resulted. Below are given some specific cases of men being overcome in railroad tunnels.

GIOVI TUNNEL.

Thirteen cases of sickness caused by gassing are reported to have occurred between the years 1888 to 1894 among trainmen passing through the Giovi Tunnel in Italy.[12] This tunnel is a little over 2 miles (3,259 meters) long. On another occasion 13 deaths resulted there from a train, of which the crew had been gassed, backing into another train outside the tunnel. Frequent cases of gassing were also reported in the Pracchia, Appenino, and South Guiseppe Tunnels between Savona and Turin, Italy.[12]

---

[10] Bulletin of the International Railway Congress, The ventilation of tunnels by Saccardo's system: Vol. 13, 1899, pp. 477–495.

[11] Churchill, C. S., The ventilation of tunnels: Railway and Eng. Rev., vol. 4, 1904, pp. 734–738.

Railway Review, Ventilation of Connaught Tunnel, Canadian Pacific R. R.: Vol. 60, 1917, pp. 901–904.

Fox, Francis, The ventilation of tunnels: Eng. News, vol. 42, 1898, pp. 131–135.

[12] Mosso, U., L'asfessia nei tunnels ed experienze coll'ossido dicarbonio fatte sul'nomo: Boll. R. Accad. Medica di Genova, An. 16, 1901, pp. 187–215.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

PONTE DECIMO TUNNEL.[13]

On August 11, 1898, a heavy freight train with three locomotives was stalled in the Ponte Decimo Tunnel near Genoa, Italy. The engineers and firemen were overcome by gas and the train rolled back down the grade, out of the tunnel and crashed into a passenger train, killing 12 people and injuring 40.

PRACCHIA TUNNELL.[13]

In 1898 a passenger train pulled by two locomotives through the Pracchia Tunnel between Bologna and Florence, Italy, arrived at the exit with both engineer and fireman unconscious, due to gas.

GRAND TRUNK TUNNEL UNDER ST. CLAIR RIVER.[14]

On October 9, 1904, a heavy freight train, pulled by a single engine, broke in two in the tunnel. A number of men were overcome in a very short time. Six men died, presumably from carbon monoxide poisoning, and others were in a serious condition when removed.

Several years prior to this accident a train was stalled in the same tunnel, with the result that the engineer, conductor, and brakeman were overcome and died from carbon monoxide poisoning.[15]

The St. Clair Tunnel is 20 feet in diameter and 2,000 yards long, single tracked, and with 2 per cent grades at the ends.

TUNNEL NO. 3, SUMMIT, WIS.

An engineer of the Chicago & North Western Railway was overcome by gas in tunnel No. 3 near Summit, Wis. His death later probably resulted from this.[16]

SCHENLEY TUNNEL, PITTSBURGH, PA.[17]

In June, 1900, a track foreman and six men were overcome while working in the Schenley Tunnel of the Baltimore & Ohio Railroad in Pittsburgh, Pa. The men were laying rails while a work train entered the tunnel and stopped, with the locomotive near by. After a time a number of men suddenly became unconscious. All cases

---

[13] Fox, Francis, The ventilation of tunnels: Eng. News, vol. 42, 1898, pp. 131–135. The ventilation of tunnels and buildings: Proc. Inst. Civ. Eng., vol. 136, Dec. 6, 1898, pp. 1–20; discussion, pp. 21–62.

[14] Editorial, Railway and Eng. Review, vol. 44, 1904, p. 740.

[15] Fox, Francis, The ventilation of tunnels: Eng. News, vol. 42, 1898, pp. 131–135.

[16] Bachelder, F. J., Report to the Public Service Commission, State of West Virginia, upon tunnel ventilation, Baltimore & Ohio Railroad tunnels between Grafton, W. Va., and Parkersburg, W. Va.: Public Service Commission, Charleston, W. Va., Mar. 10, 1916, 44 pp.

[17] Private communication to authors.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

recovered after removal from the tunnel, although several were said to have remained unconscious for a few hours.

In June, 1917, the same foreman and five men were again overcome and had to be removed from the tunnel. This accident occurred on a hot, sultry day, when the traffic through the tunnel was very heavy. All cases recovered in a short time.

This foreman and two of his men have been working in the Schenley Tunnel for many years. They spend from 4 to 15 days a month in the tunnel and are apparently in the best of health.

Details regarding dimensions of this tunnel and gas conditions under normal traffic are given later in this paper, under the heading of "Tests in Schenley Tunnel."

EXPERIMENTS ON THE USE OF GAS MASKS IN RAILROAD TUNNELS.

Through the courtesy and cordial cooperation of the United States Railroad Administration and the officials of the Baltimore & Ohio and the Pennsylvania Railroads, the authors were able to conduct extensive tests in a number of tunnels, where smoke conditions were said to be unusually bad. Various types of gas masks were worn by the authors riding in the cabs and by the engine crews in these tunnels; gas samples of the smoke-contaminated atmospheres were taken in the locomotive cabs or at the cab windows and carefully analyzed in the gas laboratory of the Pittsburgh experiment station of the Bureau of Mines. Other tests were made by trackworkers and by the authors while in a tunnel on foot.

DESCRIPTION OF GAS MASKS USED IN TESTS.

Three types of gas masks were used in these tests, as follows: (*a*) Army gas mask with standard charcoal soda-lime canister, protecting against sulphur dioxide and smoke particles, but not carbon monoxide; (*b*) carbon monoxide gas mask, which includes in addition protection against carbon monoxide; and (*c*) special "pocket" canisters or "smoke" respirators, designed to protect against sulphur dioxide and smoke, not including carbon monoxide. The first and third types of mask give protection from smoke, cinders, and all flue gases except carbon monoxide; the second type also includes carbon-monoxide protection.

ARMY GAS MASK.

Plate I, *C*, pictures an Army gas mask worn by the engineer in tests on a Baltimore & Ohio train, Monongah division, in West Virginia. The canisters are held in a haversack slung from the neck and con-

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

tain 700 c. c. (about 1½ pints) of a granular mixture of charcoal, 60 per cent by volume, and soda lime, 40 per cent; there are also two filter pads of cotton wool. The soda-lime granules contain a mixture of caustic soda, slaked lime, and Portland cement, principally. The face pieces connect to the canister by a flexible corrugated rubber tube and are of the Tissot type that form a pocket over the face so as to allow normal breathing through the nose. This mask protects against smoke and irritant gases from the stack. It does not protect against carbon monoxide.

CARBON MONOXIDE MASK.

The carbon monoxide mask was the same as the one described above except that the canister contained a granular material composed of mixtures of the oxides of manganese, copper, silver, and cobalt, known as hopcalite.[18] Hopcalite changes the poisonous carbon monoxide in air passed through it to the relatively harmless carbon dioxide; it also has some absorbing power for other gases. The hopcalite canister contained a cotton-wool filter pad and a box holding a cooling material to cool the gases.

POCKET CANISTERS.

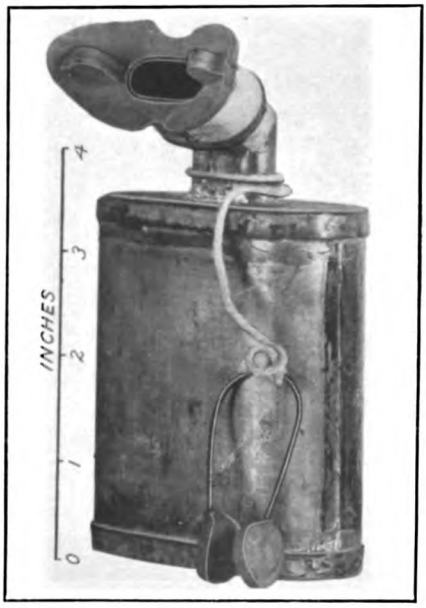
Four shapes of pocket canisters or respirators are illustrated in Plates I, *A* and *B*, and II, *A* and *B*. Figure 3 shows the details of the rectangular pocket canister. These designs were patterned after small canisters used in the Government service during the war. All have bottoms perforated with small holes above which is a screen to retain the granular charcoal-and-soda-lime absorbent; about 200 c. c. (less than ½ pint) of absorbent is used in each. On top of the absorbent is a piece of toweling to serve as a filter, then a stiff wire screen held rigidly upon the absorbent by springs. The rectangular form, Plate I, *A* and *B*, has a flat metal collar soldered to the walls inside, half-way up and extending one-fourth inch toward the center. This prevents gases channeling along the sides.

When the canisters are placed in the mouth the thin rubber leaves fit between the lips and teeth, the lugs are gripped by the teeth, breath passes in and out through the canisters. The curved stem, as in Plate I, *B*, causes less leverage on the teeth. Plate II, *A*, shows a mouthpiece which has a rubber chin rest attached. The rectangular form fits better into the pocket than the drum form, Plate II, *A* and *B*, but its resistance to breathing is greater. At 85 liters per minute flow of air the resistance amounts to 2 inches of water pressure in the drum form, and 5 inches in the rectangular form as compared with the Army canister, which has 3½ inches resistance. Five inches' re-

[18] Lamb, A. B., Bray, W. C., and Frazer, J. C. W., The removal of carbon monoxide from air: Jour. Ind. & Eng. Chem., vol. 12, March, 1920, pp. 213–221.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

A. RECTANGULAR POCKET CANISTER IN USE.

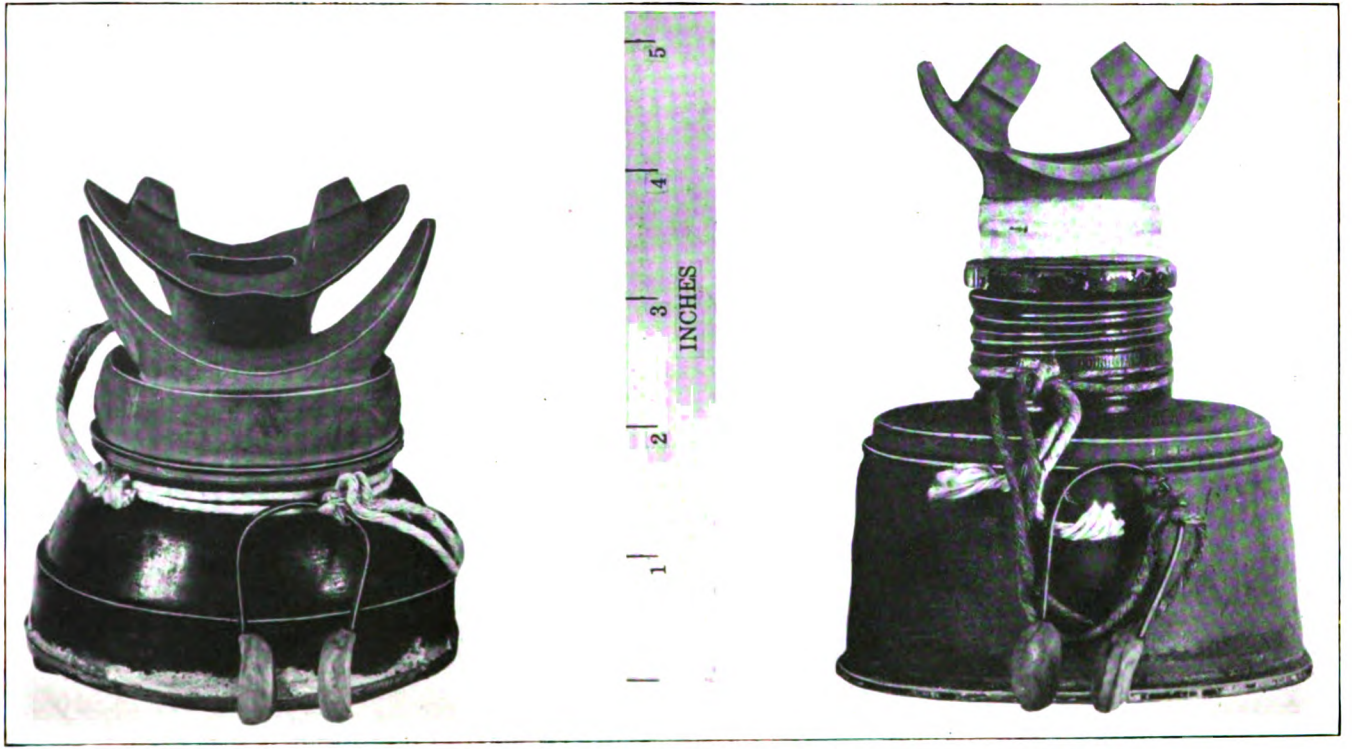


B. POCKET CANISTER WITH CURVED MOUTHPIECE.

C. ARMY GAS MASK WORN IN TESTS THROUGH TUNNELS ON MONONGAH DIVISION, BALTIMORE & OHIO R. R.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Generated on 2024-09-29 23:24 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google



A. DRUM CANISTER WITH CHIN REST TO REDUCE STRAIN ON TEETH.

B. DRUM CANISTER.

Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

sistance does not make breathing tiresome during the short time a canister is worn in a tunnel. Clips for closing the nostrils are attached by cords to each pocket canister.

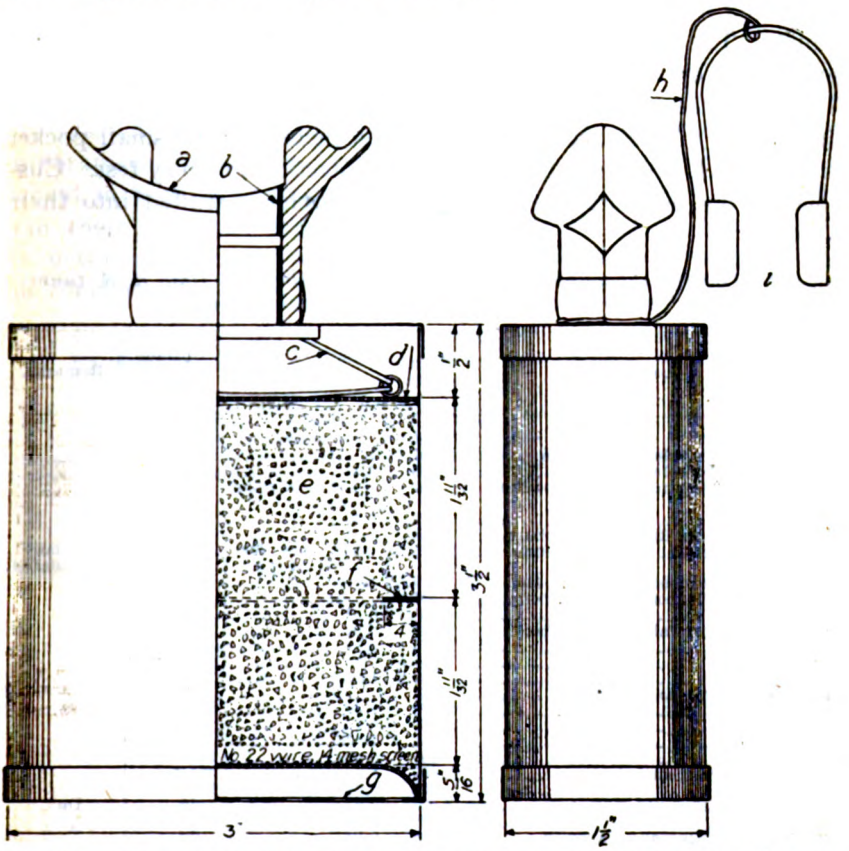


FIGURE 3.—Details of rectangular pocket canister: *a*, Rubber mouthpiece; *b*, aluminum ferrule; *c*, No. 15 wire spring; *d*, Turkish toweling filter-pad under screen of 14-mesh No. 22 wire; *e*, charcoal, soda, and lime mixture; *f*, baffle; *g*, holes, ¼-inch diameter; *h*, cord; *i*, nose clip.

TESTS IN WEST VIRGINIA TUNNELS.

Tests were made in 23 tunnels of the Baltimore & Ohio Railroad, Monongah division, Parkersburg branch, between Grafton and Parkersburg, W. Va. In these tunnels the masks were tested in cabs on two heavy-duty freight locomotives hauling freight trains, one going west, another east. Table 2 gives the locations, lengths, and grades of the tunnels, all of which are single-tracked and have a clearance of about 17½ feet above the track. This clearance corresponds to practice of 50 years ago when locomotives were small and trains much lighter than to-day, modern tunnels commonly providing 22 feet or more clearance. The 23 tunnels, of small sectional area, with lengths

Generated on 2024-09-29 23:21 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ranging up to 2,700 feet and grades up to 1 per cent, make operation of freight trains over the Monongah division exceedingly difficult for trainmen. It is customary to reduce weight of the trains to lessen the smoke and heat generated by locomotives while passing through the tunnels. The masks tested on the Monongah division were thus subjected to severe conditions.

The engineers, fireman, and two of the authors each wore in the tunnels one of the three types of masks, including the small pocket canister. All declared they had good protection in every test. Customarily the men breathe through handkerchiefs stuffed into their mouths.

TABLE 2.—*Locations, lengths, and grades of the Baltimore & Ohio R. R. tunnels of the Parkersburg branch, Monongah division.*

Tunnel No.	Location.	Total length.	Grade.	Upgrade east or west.	Remarks.
		Feet.	*Per cent.*		
1	Between Clarksburg and Ocean	2,707.6	1	West	
2	Between Bristol and Maken	1,086	0.81	East	
3	Between Morgansville and Long Run	282	+0.03, 0.36 going out.	West	
4	do	846	0.40	do	
5	Between Rock Run and Smithburg	359	0.41	do	
6	Between Central and West Union	2,313.5	+0.02, few feet −0.31 going out.	do	Artificially ventilated.
7	Between Pennsboro and Toll Gate	779.5	Level		
8	Between Ellenboro and Pennsboro	587.8	do		
9	do	855.1	0.85	do	
10	Between Cornwallis and Ellenboro	337	0.01	East	
11	do	175.5	0.11	do	
12	do	748.5	0.53	do	
13	do	352.5	Level		
14	Between Cairo and Cornwallis	183	do		
15	do	478	0.86	East	
16	do	221	0.2	do	
17	do	451	Level		
18	do	965	0.07	East	
19	Between Petroleum and Cairo	1,495	1	West	
20	do	254.2	0.34	East	
21	Between Eaton and Walker	2,020	0.97	do	Do.
22	do	338	1	do	
23	Between Walker and Kanawha	286	0.04	do	

Although this gives some relief from the smoke particles and heat, the choking gases and vapors cause discomfort. During the tests, when only a handkerchief was used, the sulphur dioxide often caused intense throat irritation and coughing. The eyes were often closed by irritation; rubber-edged goggles prevented this and they may be used with pocket canisters when desired.

One fireman demonstrated that he could fire, with only small hindrance, for 15 minutes while wearing an Army gas mask, but, because of the need of lessening smoke, firing is not usual in tunnels.

DISCUSSION OF RESULTS OF WEST VIRGINIA TESTS.

Table 3 gives the results of observations and analyses of gases from locomotive cabs in tunnels where conditions were severe. All cab windows were closed during these tests. In every test each type

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

of mask provided good protection and made the trip much easier; the heat remained a discomforting condition. Temperatures recorded in Table 3 were determined with an accurate chemical thermometer, mercury filled. It was hung in air near the windows on one side; windows were always closed when in tunnels. The thermometer did not show actual temperature at any one time because of its very considerable lag, and temperatures varied with the air currents. A maximum of 131° F. is indicated, but sometimes the temperatures must have been much higher. Occasionally the air seemed to burn the ears, and it is not uncommon for trainmen to have their ears and noses peel after such burning. Throughout this period of high temperature the air from the masks remained cool and comfortable.

TABLE 3.—*Results of tests in locomotive cabs in some of the tunnels on the Baltimore & Ohio R. R. between Grafton and Parkersburg, W. Va.*

[Tunnels single tracked, about 17½ feet clearance. June 18, 1919: Train west, No. 74; freight, 23 cars, 900 tons, heavy-duty freight engine, No. 2896. June 19, 1919; train east, No. 79; freight, 26 cars, 900 tons, heavy-duty freight engine, No. 2844. Normal air contains 0.03 per cent carbon dioxide, 20.93 per cent oxygen, and 79.04 per cent nitrogen. Gas samples represent air breathed in locomotive cabs with closed windows.]

Tunnel No.	Length.	Grade.		Train bound east or west.	Estimated speed.	Estimated time in tunnel.	Maximum temperature in cab by mercury thermometer.	Smoke in air at time of taking sample.	Analyses of air in cab[1].					
		Per cent.	Upward east or west.						Laboratory No.	Per cent by volume. Carbon dioxide (CO_2).	Carbon monoxide (CO).	Oxygen (O_2).	Nitrogen (N_2).	Sulphur dioxide (SO_2), parts per million.
	Ft.				*Mi. per hr.*	*Min*	*° F.*							
1	2,708	1.0	West..	West..	5	6½	131	Smoky..	10935	0.95	0.10	19.90	79.05	.....
1	2,708	1.0	...do..	...do..	5	6½	131	...do....	10936	.50	.00	20.40	79.10	[2] 156
2	1,086	.81	East..	...do..	8	1½	86	...do....	10937	.05	.00	20.87	79.08	105
4	846	.40	West..	...do..	10	1	77	...do....	10938	.03	.00	20.91	79.06	87
5	359	.41	...do..	...do..	10	½	86	Heavy smoke.	10939	.12	.06	20.84	78.98	108
5	359	.41	...do..	East..	10	½	77	...do....	10940	.39	.02	20.52	79.07	83
6	2,314	.31	East..	West..	10	2½	86	Nearly clear.	10941	.14	.01	20.87	78.98	[3] 132
7	780	Level.	.....	...do..	10	1	77	...do....	10943	.82	.00	20.19	78.99	.....
8	588	Level.	.....	East..	15	½	86	...do....	10944	.31	.02	20.59	79.08	96
9	855	.85	West..	West..	10	1	104	...do....	10945	.77	.04	20.09	79.10	156
12	749	.53	East..	...do..	10	1	77	...do....	10946	.08	.02	20.85	79.05	116
19	1,495	1.0	West..	East..	13	1½	131	...do....	10947	.64	.00	20.21	79.15	79
21	2,020	.97	East..	...do..	13	2	68	...do....	10948	.88	.00	20.00	79.12	[3] 105

[1] No methane or hydrogen was found in any sample.
[2] The Army gas mask, carbon monoxide gas mask and small pocket canister filtered out all smoke and sulphurous fumes in all of the 23 tunnels, a total of 46 passages through tunnels.
[3] Tunnel artificially ventilated.

Smoke was bad in all tunnels except the ventilated tunnels; in addition, the air was charged with dust and cinders. None of these could be noticed in the air breathed through the canisters. The pocket

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

canister containing only a filter of Turkish toweling gives almost no protection against wood smoke or tobacco smoke, which consist mostly of very small liquid particles, but locomotive smoke was held by it. This is probably due to the latter being largely carbonaceous material in bigger particles, or such smaller particles as penetrated the canister were nonirritating and produced no sensation. Samples of air for the analyses were taken in locomotive cabs instantaneously by the vacuum bottle method.[19] Since the air was continually changing and not very uniform, the analyses show only momentary conditions, probably the mean of the analyses would represent average air during the tests. Carbon monoxide is the only poisonous constituent found in smoke. The maximum concentration of 0.10 per cent is not sufficient to affect men during the time a moving train is normally in a tunnel, and men can remain indefinitely in the average concentration of 0.02 per cent without ill effect. When a locomotive stalls, the proportion of carbon monoxide may increase until it becomes dangerous. In this event only the hopcalite canister protects fully. However, need of protection against carbon monoxide is infrequent and need not be provided as regular equipment for ordinary service.

The sulphur-dioxide content ranged up to 156 parts per million. The results are probably too low because of some unavoidable oxidation [20] before the samples could be analyzed. The high concentration of 156 parts per million produces smarting of the eyes, a flow of tears, and strongly irritates the nose and throat, so that breathing is difficult.[21] Each mask completely removed all sulphur dioxide. Seidell and Meserve [20] took samples of air through the windows of passenger coaches passing through ventilated tunnels of the Baltimore & Ohio Railroad at Baltimore, Md., but here they found a maximum of 15 parts per million of sulphur dioxide.

Of the other gaseous constituents of the air, carbon dioxide was increased above normal; however, the maximum of 0.95 may be easily breathed without ill effects. Masks containing soda lime remove some of the carbon dioxide. The oxygen and nitrogen content of the air were not changed enough to cause physiological effects.

Altogether these tests show that each mask provided comfortable breathing in very hot, smoky, dusty, and sulphurous atmospheres.

---

[19] Burrell, G. A., and Seibert, F. M., The sampling and examination of mine gases, and natural gas: Bull. 42, Bureau of Mines, 1913, 116 pp.

[20] Seidell, R., and Meserve, P. W., Gaseous impurities in the air of railway tunnels: Hygienic Laboratory, Treasury Dept., Bulletin 92, 1914, 47 pp.

[21] Holmes, J. A., Franklin, E. C., and Gould, R. A., Report of the Selby Smelter Commission: Bull. 98, Bureau of Mines, 1915, 525 pp.; Jones, G. W., Capps, J. H., and Katz, S. H., Simple method for determining sulphur dioxide: Min. and Sci. Press, vol. 117, 1918, pp. 415–418.

Generated on 2024-09-29 23:22 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

TESTS IN THE GALLITZIN TUNNELS.

The Gallitzin Tunnels of the Pennsylvania Railroad are at the crest of a 1.75 per cent grade extending from Altoona, Pa., west to the tunnels, where the grade reduces to 1 per cent. Three tunnels are constructed for the several tracks of the railroad. No 4 track tunnel, in which masks were tested, is the longest, 3,606 feet; it is double tracked, has 27½ feet clearance, and the grade has a slight curve at the west end. No artificial ventilation was used during the tests, although a ventilating fan is placed at the eastern portal. Traffic here is unusually heavy; trains of 2,600 tons or more requiring three or four locomotives are frequent. Usually three locomotives are used, one ahead and two pushers.

Mask tests were made in locomotive cabs on two heavy trains. Gas samples were taken just outside the fireman's open window. Results are given in Table 4.

TABLE 4.—*Results of tests in locomotive cabs in Gallitzin No. 4 track tunnel, Pennsylvania Railroad, 12 miles west of Altoona, Pa.*

[Tunnel is 3,606 feet long, 27½ feet clearance, double tracked, 1.03 per cent grade upward going west; approach to tunnel has 1¾ per cent grade extending from Altoona. August 29, 1919: Train west, freight, 55 cars, 1,718 tons, three engines on train, two in rear, latter were No. 2256 and No. 3716. Train west, freight, 56 cars, 2,660 tons, two engines on train, one in rear, No. 6227 was stoker fired.]

Smoke in air at time of taking gas sample.	Time of sampling.	Laboratory No.	Analyses of air in cab outside fireman's open windows. Per cent by volume. Carbon dioxide (CO_2).	Carbon monoxide (CO).	Hydrogen (H_2).	Oxygen (O_2).	Nitrogen (N_2).	Sulphur dioxide (SO_2),[1] parts per million.
Aug. 29, 1919:								
Clear	3.20	11369	0.55	0.03	0.00	20.43	78.99	[2] 20
Heavy smoke	3.24	11371	1.00	.05	.00	19.82	79.13	.....
Clearing rapidly	3.26	11372	.65	.02	.00	20.21	79.12	[3] 10
Smoky	3.35	11373	.45	.02	.00	20.50	79.03	20
Nearly clear	3.45	11370	.24	.00	.00	20.75	79.01	[4]
Aug. 30, 1919:								
Smoky	2.30	11364	.34	.02	.01	20.62	79.01	[5] 60
Do	2.30	11363	.66	.01	.00	20.25	79.08	.....
Do	2.31	11365	.91	.01	.00	20.04	79.04	[6]
Do	2.31	11366	.57	.00	.00	20.39	79.04	10
Do	2.32	11368	.88	.02	.00	20.08	79.02	40
Do	2.32	11367	.57	.00	.00	20.40	79.03	20
Do	2.33	11374	.04	.00	.00	20.95	79.01	.....

[1] Army gas masks, carbon monoxide masks, and pocket canister, all gave good protection.
[2] Immediately after this sample was taken train stalled 25 minutes in tunnel. Speed while sampling was 4 miles per hour.
[3] Maximum temperature observed during stop was 162° F. above the roof of the cab; most of the time temperature in the cab was 126° F.
[4] Sample taken as train was starting. Total time in tunnel was about 30 minutes.
[5] Speed through tunnel was 4 miles per hour; time in tunnel 5½ minutes.
[6] Maximum observed temperature, 126° F.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

The first train consisted of 55 cars, 1,718 tons, one engine pulling and two pushing. Both of the rear crews wore masks of the several kinds but mostly Army type; one of the authors rode on the rear locomotive where smoke was densest. To lengthen the time in the tunnel and put more work upon the two rear locomotives, instructions had been issued that the head engine shut off steam at the tunnel. The fireman shoveled coal up to the portal of the tunnel. Thick, black smoke came from the stacks before and after the tunnel was entered, but the density gradually decreased after firing stopped. When the two rear locomotives were midway through the tunnel an air hose broke and the train stopped for 25 minutes. Most of the time a thermometer hanging near the fireman's seat indicated 126° F.; a thermometer held above the roof of the cab showed 162°. Though black, heavy, hot smoke poured into the cabs, the canisters always gave good and comparatively cool air. Without the canisters breathing was very difficult, though a good natural draft rapidly carried the smoke away.

The second train consisted of 56 cars, aggregating 2,660 tons. One engine pulled and one pushed, the latter being fired by a Duplex mechanical stoker. Both engine crews and some of the brakemen wore masks. The speed of the train was slow, 4 miles per hour. Smoke conditions were about the same as in the previous test.

A total of 14 men wore masks during the two trips and all persons stated that no smoke or distasteful gas had penetrated.

After the tests Army gas masks with the nose-breathing type of face piece were left for further use by the engineers, who, after a month's trial, were unanimous in stating that the protection was perfect but that the infrequent need and the trouble of caring for and carrying the bulky gas masks made them impracticable at the Gallitzin Tunnel.

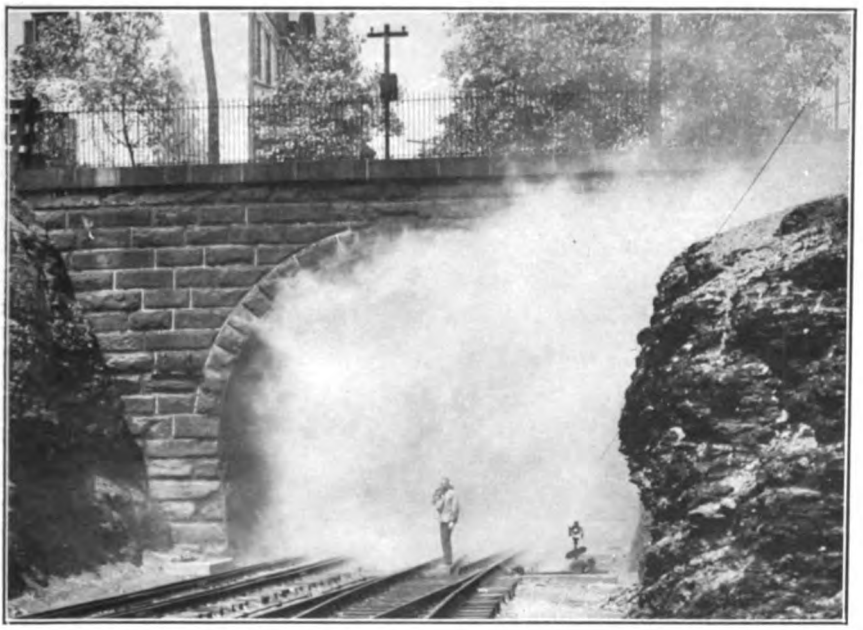
TESTS IN THE SCHENLEY TUNNEL.

The Schenley Tunnel of the Baltimore & Ohio Railroad is in the city of Pittsburgh. It is double tracked, 2,872 feet long, has 21½ feet clearance, a grade of 0.62 per cent eastward, and a slight curve near the eastern portal. The traffic comprises considerable switching and heavy freight and passenger trains. Natural ventilation is used and as the locomotives often follow each other closely, smoke may accumulate when the draft is poor.

Plate III, *A* and *B*, shows the eastern portal when clear and with smoke rolling out after passage of a train. Plate III, *B*, makes evident the difficulty of breathing in the tunnel. In tests on locomotives in the Schenley Tunnel only the small pocket canisters were tried; 10 engineers and firemen who used them were unanimous in stating that

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

A. SCHENLEY TUNNEL, BALTIMORE & OHIO R. R., PITTSBURGH, PA., BEFORE PASSAGE OF TRAIN.



B. SCHENLEY TUNNEL AFTER PASSAGE OF TRAIN, SHOWING SMOKE.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

the canisters filtered out all irritating constituents. They much preferred the pocket canisters to the Army gas masks, and some said they would be glad to provide themselves with the canisters if available. Four canisters were left with engineers and firemen engaged in local freight traffic and switching and who pass the Schenley Tunnel two to four or more times daily on heavy trains. The canisters used by them lasted a minimum of 10 weeks before smoke or sulphur gas penetrated. Both the drum and the rectangular form of pocket canister were used. Some trainmen expressed no preference; others preferred the rectangular form.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

TABLE 5.—*Analyses of air breathed by trackworkers after passage of trains in Schenley Tunnel, Baltimore & Ohio R. R., Pittsburgh, Pa.*[1]

[Tunnel is 2,872 feet long; double tracked; 21½ feet clearance; grade, 0.62 per cent eastward; slight curve near eastern portal. Date of test, Aug. 5, 1919. Air samples were taken by vacuum-bulb method in middle of tunnel, 5 to 6 feet above ground.]

Time of passage, a. m.	Description of train.				Maximum temperature.	Direction of draft, east or west.	Time required to clear tunnel.	Smoke in air at time of taking sample.	Laboratory No.	Analyses of air, per cent by volume.					Parts per million sulphur dioxide (SO_2).
	Type of train.	Number of cars.	Direction, east or west.	Speed						Carbon dioxide (CO_2).	Carbon monoxide (CO).	Hydrogen (H_2).	Oxygen (O_2).	Nitrogen (N_2)	
				Mi. per hr.	*° F.*		*Minutes.*								
8.00	None				64	East		Clear	11172	0.07	0.05		20.79	79.09	
8.10	Locomotive only [2]		East	10	64	do		Light smoke	11171	.23	.05	.01	20.62	79.09	50
8.15	do		West	10	64	do	3	do							
8.18	Passenger	6	East	15	64	do	4	do	11173	.14	.05	.01	20.68	79.12	10
8.28	do	3	West	15	64	West	4	do	11174	.08	.01		20.78	79.13	20
9.30	do [3]		do	10	64	do		Clear	11176	.10	.08	.01	20.74	79.07	30
9.32	Locomotive only		do	10	64	East		Light smoke							
9.35	do		do	10	64	do		do							
9.35	do [4]		do	10	64	West	7	Smoky							60
10.05	Passenger [5]	8	do	15	64	do	10	Clear	11178	.16	.04	.02	20.69	79.09	40
10.25	Freight [5]	35	East	8	86	do		do	11177						30
10.26	do [6]	35	do	8	104	do	24	Heavy smoke	11180	1.03	.12	.03	19.67	79.14	110
10.36	Two locomotives only.[7]		West	10	64	do		Smoky							
11.16	do		do	10	64	do		Clear							
11.17	Passenger		East	15	64	do		Smoky	11179	.34			20.39	79.27	20
12.00	Freight [5]	35	do	8	86	do	20	Clear	11181	.32	.01		20.50	79.17	20
12.01	do [6]	35	do	8	113	do		Heavy smoke	11182	.43	.05	.02	20.49	79.01	30
12.05	None [8]				64	East		do	11183	.31	.05	.02	20.59	79.03	

[1] Pocket canisters only were used; they gave full protection.
[2] Smoke cleared quickly.
[3] Unprotected men coughed.
[4] Tunnel had not cleared of smoke from two preceding locomotives. Draft changed direction soon after train passed.
[5] Locomotives on front and rear. Sample taken just after first locomotive passed.
[6] Sample taken just after rear locomotive passed.
[7] Tunnel still smoky from train.
[8] Draft reversed itself.

Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Trackworkers are employed in the Schenley Tunnel for 4 to 15 days a month, and they often have to endure smoky atmospheres for longer periods than trainmen. No work is done when the air is bad, and the men usually try to protect themselves by breathing through handkerchiefs. Samples of the air breathed by trackmen after trains had passed were analyzed; results are given in Table 5. A maximum of 0.12 per cent carbon monoxide and 110 parts per million of sulphur dioxide were found. This atmosphere is very irritating because of the sulphur dioxide content; it also contains enough carbon monoxide to produce headache and nausea if breathed for a half hour. On the morning of the tests the worst conditions after the passage of a train rapidly subsided, but they may not when the natural draft is poorer. The trackmen who used the pocket canister reported it satisfactory for filtering out smoke and sulphur fumes.

GENERAL DISCUSSION OF RESULTS OF TESTS.

The results of the various tests described in this report obviously apply to the ordinary working conditions in railroad tunnels. The authors had no opportunity of investigating such extraordinary conditions as must have occurred at the times when men were overcome. The highest percentages of carbon monoxide found were 0.12 per cent in the Schenley Tunnel just after the rear locomotive of a train with front and rear locomotives had passed by; and 0.10 per cent in a sample from the cab of a freight locomotive in one of the unventilated West Virginia tunnels of one-half mile length and 1 per cent grade. These percentages of carbon monoxide were associated with 1.03 and 0.95 per cent carbon dioxide, respectively, also the highest percentages of carbon dioxide found. Many of the samples contained 0.02 to 0.05 per cent carbon monoxide—not enough to demand the use of a carbon monoxide respirator, as even 0.12 per cent carbon monoxide can be breathed for 10 to 15 minutes without ill effect.

The sulphur dioxide content of the samples from the West Virginia tunnels usually ranged from 80 to 150 parts per million (0.008 to 0.0150 per cent by volume). In the Schenley and Gallitzin tunnels the sulphur dioxide was less than half as much, probably because of the use of higher sulphur coal in the West Virginia tests. In all the tests, however, enough sulphur dioxide was present to be extremely irritating.

The highest temperature recorded in the cab in passing through the West Virginia tunnels was 131° F. In the Gallitzin Tunnel the maximum temperature on a continuous run through the tunnel was 126° F. On the occasion when the engine stopped in the tunnel the maximum temperature in the cab was 126° F. Just above the cab roof a temperature of 162° F. was observed. In fact it is

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

a question whether these excessive temperatures combined with high humidity from exhaust steam have not been an equally important factor in the casualties attributed to carbon monoxide. One who has never ridden in the cab of a locomotive through a long unventilated tunnel can not appreciate the extreme discomfort, at times real suffering, caused by the hot, steamy, sulphurous gases from the locomotive stack.

In one of the tests in the Schenley Tunnel, on a heavy train of iron ore, one locomotive was in front and two in rear. The last locomotive was backed to the preceding one so that smoke from the stack ahead had more direct access to the rear cab. The thermometer registered only 130° F. but discomfort was greater than in any other test, possibly because of a higher humidity. During this trip the fireman put his head and shoulders and as much as possible of his body into the narrow locker at the side of the tender. Added to the heat is the difficulty of breathing the smoky, sulphurous, choking atmosphere, so that altogether the conditions are probably as uncomfortable as any that men are called upon regularly to endure. Fortunately the passage through tunnels is usually of short duration.

All of the discomfort can be eliminated only by the substitution of electric for steam locomotives or by artificially ventilating the tunnels. Although both systems are very expensive, necessity sometimes forces their adoption.

TYPE OF GAS MASK OR RESPIRATOR BEST SUITED FOR USE IN TUNNELS.

The difficulties in breathing can be eliminated by using the Army-type gas mask or the small pocket canister, both of which remove smoke and sulphur fumes from the inspired air. In general, the pocket canisters have been preferred because of their convenience and small cost; their effective life of two or three months is ample.

Possibility arises when a train is stalled and there is no atmospheric movement of men wearing masks with charcoal and soda-lime canister being subjected to asphyxiation by carbon monoxide even though protected from smoke and sulphur fumes. This hazard is possible because trainmen have at times been asphyxiated,[22] but it is unusual. The authors did not find dangerous amounts of carbon monoxide in any tests, including one in which a train with three locomotives was stopped. The highest concentration of carbon

[22] Editorial, Railway and Eng. Rev., vol. 44, 1904, p. 140. Fox, Francis, The ventilation of tunnels and buildings: Proc. Inst. Civ. Eng., vol. 136, 1898, pp. 1–20; discussion, pp. 21–87. The ventilation of tunnels: Eng. News, vol. 42, 1899, pp. 131–135. Bachelder, F. J., Report to the Public Service Commission upon tunnel ventilation, Baltimore & Ohio R. R. tunnels between Grafton, W. Va., and Parkersburg, W. Va.: Public Service Commission, Charleston, W. Va., Mar. 10, 1916, 44 pp.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

monoxide even momentarily indicated by the present tests was 0.12 per cent, not enough to produce serious consequences if breathed for 30 minutes.[23]

If protection against carbon monoxide is desired for extraordinary or exceptional conditions, it might be advisable to carry several carbon monoxide masks as emergency equipment. For ordinary service conditions, the rectangular form of pocket canister with curved mouthpiece, as shown in Plate I, *B*, and figure 3, will be found to provide adequate protection from sulphur fumes and smoke. It is convenient and cheaply made.

OTHER USES OF THE POCKET CANISTER.

Pocket canisters, or respirators, were used satisfactorily, especially during the war, in many departments of the Government where workers were occasionally and for short periods of time exposed to low concentrations of poisonous gases; a common service was that of an emergency respirator to enable persons to escape from buildings when poisonous gas had been accidentally liberated.

The charcoal and soda-lime filled canister protects against acid gases such as chlorine, formic acid, hydrogen chloride, hydrogen cyanide, hydrogen sulphide, nitrogen peroxide, phosgene, and sulphur dioxide; and against organic vapors such as acetone, alcohol, aniline, benzene, carbon bisulphide, carbon tetrachloride, chloroform, ether, formaldehyde, toluene, and similar volatile compounds. They should not be used in gasoline vapor because of their very low capacity for this vapor; they afford no protection against ammonia, and none whatever against the carbon monoxide which may be found in products of combustion, and in producer gas, coal gas, water gas, and blast-furnace gas. The pocket canisters afford protection against the coarse smoke particles of locomotive smoke; but, as used in the tests described, give very little protection against wood smoke, very fine dusts, and fumes or mists such as those of tin tetrachloride, silicon tetrachloride, or sulphur trioxide. Filters of cotton wool can be placed in the drum-form pocket canister to increase the protection against smokes, mists, and the like, but not in the rectangular form because of increasing the breathing resistance beyond tolerable limits.

Pocket canisters contain one-fourth to one-third the quantity of absorbent held by the standard Army canister, and their capacity for holding gas is reduced correspondingly. Moreover, the activity against higher concentrations of poisonous constituents in air is reduced because of the small cross section and low column of absorbent that reduces the duration of contact between gas and absorbent.

[23] Haldane, J., The action of carbonic oxide on man: Jour. Physiol., vol. 18, 1895, pp. 430–462.

Generated on 2024-09-29 23:22 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Although it has many limitations, the pocket canister provides convenient protection against mild concentrations of poisonous gases and vapors in air and against coarse dust and large carbonized smoke particles. Its action is similar to that of the standard Army gas mask, but with reduced capacity and activity. In the industries many atmospheres may exist in which pocket canisters can reduce hazards to workmen.

If desired, inhalation and exhalation valves may be provided on the canister in order to avoid loading the absorbent material with carbon dioxide and water vapor from the exhaled air, which in the simple form passes out through the canister. Such a modification was suggested for the use of workmen handling hydrocyanic acid.

SUMMARY AND CONCLUSIONS.

Unventilated railroad tunnels contain locomotive smoke and choking, sulphurous gases that make breathing very difficult for exposed trainmen, especially those on the locomotive. The temperatures in locomotive cabs while passing through tunnels have been found to range up to 162° F. High humidity from exhaust steam augments the discomfort and difficulty in breathing due to smoke and sulphur dioxide. Trackworkers are subjected to similar discomforts after trains have passed.

Tests were made in railroad tunnels with Army gas masks, carbon monoxide masks, and with special smoke respirators. The latter consisted of small canisters that fit conveniently into a coat pocket and are held in the mouth by a mouthpiece. The canisters were filled with an absorbent mixture of activated charcoal and soda lime and contained filters of Turkish toweling. Both the pocket canisters and Army gas masks gave complete protection in the tunnels against sulphur dioxide, irritating vapors, and smoke.

The pocket canisters are much more convenient to carry than the Army gas masks, but have a lesser capacity for gases. However, they were found to last a minimum of two months in rather severe service in the Schenley Tunnel of the Baltimore & Ohio Railroad at Pittsburgh, Pa., a life that is ample for practicability.

The small pocket canisters are also convenient for protection against many poisonous gases and vapors found in industry, especially for infrequent use in low concentrations of acid gases and organic vapors in air.

ACKNOWLEDGMENTS.

The authors wish to acknowledge the generous cooperation and assistance given by the Baltimore & Ohio and the Pennsylvania Railroads, and to the assistance in tests and many helpful suggestions by Supt. C. W. Van Horn, Engineers R. L. Campbell and W. S.

Generated on 2024-09-29 23:21 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Sinnett, and Firemen R. P. Whittach and J. C. Riley of the Monongah division, Baltimore & Ohio Railroad; by Supt. C. B. Gorsuch, Engineer E. T. Dillard, and Fireman F. B. Nellis, of the Pittsburgh division, Baltimore & Ohio Railroad; and by Supt. R. T. Morrow, Assistant Road Foreman of Engines H. G. Gentsell, Engineers W. R. Shont and H. W. Wilson, and Firemen R. C. Smith and E. M. Genter, of the Western Pennsylvania division, Pennsylvania Railroad.

PUBLICATIONS ON GAS MASKS AND BREATHING APPARATUS.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable from the Superintendent of Documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

TECHNICAL PAPER 82. Oxygen mine rescue apparatus and physiological effects on users, by Yandell Henderson and J. W. Paul. 1917. 102 pp., 5 pls., 6 figs.

TECHNICAL PAPER 248. Gas masks for gases met in fighting fires, by A. C. Fieldner, S. H. Katz, and S. P. Kinney. 1921. 62 pp., 9 pls., 5 figs.

MINERS' CIRCULAR 4. The use and care of mine rescue breathing apparatus, by J. W. Paul. 1911. 24 pp., 5 figs.

PUBLICATIONS THAT MAY BE OBTAINED ONLY FROM THE SUPERINTENDENT OF DOCUMENTS.

BULLETIN 82. International conference of mine experiment stations, Pittsburgh, Pa., September 14–21, 1912, compiled by G. S. Rice. 1914. 99 pp., 4 figs. 15 cents.

TECHNICAL PAPER 77. Report of the committee on resuscitation from mine gases, by W. B. Cannon, G. W. Crile, Joseph Erlanger, Yandell Henderson, and S. J. Meltzer. 1914. 35 pp., 4 figs. 5 cents.

Generated on 2024-09-29 23:20 GMT / https://hdl.handle.net/2027/uiug.30112111813561
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN